The Reactor Safety Program

by Kaye D. Lathrop

Although Los Alamos has had a long history of individual contributors to the safety of reactors, including Hans Bethe, George Bell, and William Stratton, the reactor safety research program now conducted by the Energy Division began in 1972 in the Theoretical Division. At that time, in reactor physics and safety circles, there was a slowly increasing realization that our ability to predict the consequences of possible reactor accidents was woefully inadequate. The safety review process for the Fast Flux Test Facility at Richland, Washington had resulted in a heated and prolonged debate between the safety analysts at Argonne National Laboratory and the construction project managers at Hanford because the results of the safety analysis implied greatly increased design and construction expense. Somewhat earlier, the first major performance tests of a simulated light-water reactor emergency core-cooling system at the Semiscale Facility at Idaho Falls gave an unforeseen result. The emergency cooling water, instead of penetrating the core and cooling the system, simply flowed around the upper annulus of the apparatus and exited through the simulated pipe break. Although the Semiscale apparatus was about one-thousandth as large as an actual reactor, these disturbing results precipitated a lengthy set of hearings that culminated in a Code of Federal Regulations that limited the operating temperatures of existing and future reactors. Because of a lack of understanding of what would happen in a full-size reactor, these regulations embodied many "conservatisms" and in this sense were arbitrary.

So there existed a desperate need for an analytic predictive capability, especially because expense had prohibited and always would prohibit complete full-scale testing of safety systems. Jay Boudreau, William Reed, and I, members of the Transport Theory Group of the Theoretical Division, saw this need as an opportunity, each in a different way. Boudreau, who had written his doctoral thesis on possible supercritical configurations that might emerge from core rearrangements during fast reactor accidents, wanted to turn from his transport theory assignments to solve what he believed were truly important problems. Bill Reed, who had already demonstrated a brilliant mastery of computational transport theory, was anxious to extend his talents to hydrodynamics. And I had an implicit faith in the ability of a properly designed computer code to make correct predictions and was anxious for a new challenge. Further, in the reduction-in-force days of the early seventies, I needed new financial support for my group.

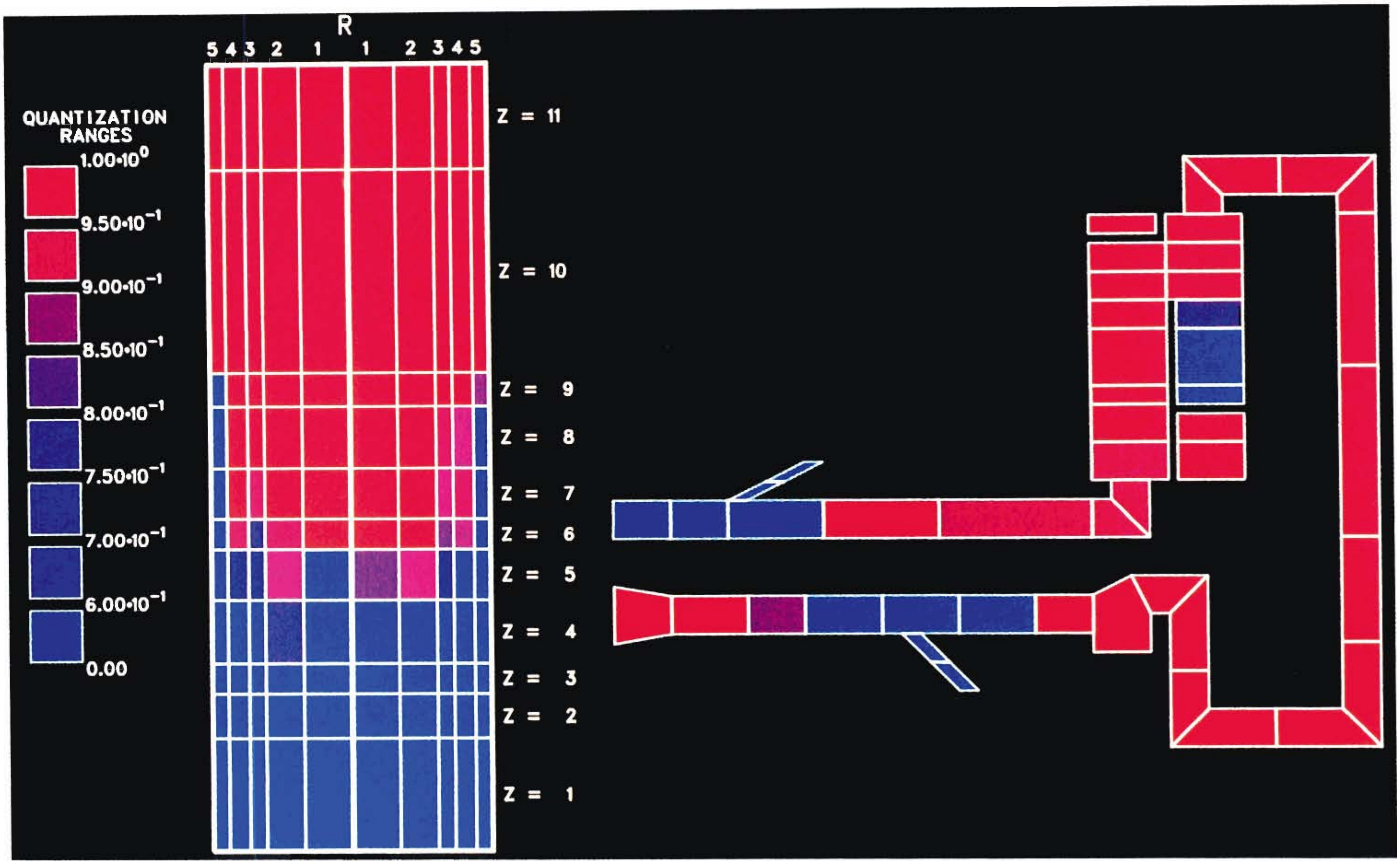
In my first 1972 foray to Washington, I was greeted by a skeptical branch chief with the sally, "Who are you, and what are your credentials?" However, in a widely attended Washington meeting on October 31, 1973, we presented a detailed proposal, authored by Jay Boudreau, Frank Harlow, Bill Reed, and Jack Barnes, for the development of the SIMMER (an acronym for S_n, implicit, multifield, multicomponent, Eulerian, recriticality) code to analyze fast reactor core-meltdown accidents. Although Los Alamos was outside the reactor safety community, the Laboratory's acknowledged leadership in computational methods and the existence of three groups in the Theoretical Division devoted to transport theory, hydrodynamics, and equation-of-state research convinced the AEC of our competence,

The proposal was funded, and work on SIMMER began in earnest in 1974. That same year, William Kirk and I began a more broadly based reactor safety research program on high-temperature gas-cooled reactors. Simultaneously, and almost as an afterthought, Reed and I agreed to develop a best-estimate computer code (subsequently named TRAC for transient reactor analysis code) to predict the effects of emergency core-cooling systems in light-water reactors. In retrospect, our self-confidence was astounding. We were blissfully ignorant of the difficulty of the task, and Los Alamos, despite long experience with high-temperature gas-cooled reactors and fast reactors, had no expertise with light-water reactors.

The Transport Theory Group grew rapidly in 1974 and 1975, becoming three groups in December of the latter year. Two of these groups formed the nucleus of the present 125-man reactor safety program in the Energy Division. The research of this program is the theme of the Summer/Fall 1981 issue of *Los Alamos Science.* The third group, headed by Warren Miller, remained as the Transport Theory Group of the Theoretical Division.

The success of the SIMMER and TRAC computer codes has been especially noteworthy because they must extrapolate. That is, they must make believable predictions outside the domain of experimental results. Versions of TRAC, in particular, have been used to predict results for dozens of experiments on many reactor components of scales up to full size and on integrated systems of various miniature scales. (The only full-scale, full-system data point for a light-water reactor emergency cooling system is Three Mile Island.) TRAC has a convincing predictive record. No other computer model of similar complexity, certainly not those of weapons design codes, can extrapolate with such confidence. SIMMER, while not yet as exhaustively compared with experiment as TRAC, has made two valuable predictions. First, contrary to previously accepted dogma, secondary and subsequent critical configurations can occur because of a core rearrangement during the course of a fast reactor accident. Second, and notwithstanding this first prediction, the energy released (and hence the containment expense) in fast reactor core-melt accidents is computed to be much less than previously predicted.

In addition to these technical achievements and of equal importance, the growth of the reactor safety program brought to Los Alamos many extremely capable people. These include Jim Jackson, who came from



Two examples of TRAC results. The graphic output shown here is color coded (left) according to the fraction of vapor or steam in each computational cell. One example (middle) shows liquid water (blue) in the bottom of a pressurized-water reactor vessel filled with steam (red) following a postulated complete break in the largest coolant pipe leading into the vessel. The unique ability of TRAC to analyze 3-dimensional fluid motions in a vessel coupled to a full reactor system is proving valuable in addressing a wide variety of possible accidents in pressurized-water reactors. The output on the right shows steam-water flows in a loop of the Upper Plenum Test Facility (UPTF). Now in the design stage, this West German facility will include a full-sized vessel and several coolant loops to allow accurate simulations of fluid behavior during the core-reflooding stage of a large-break loss-of-coolant accident in a pressurized-water reactor. TRAC is being used extensively in the design of UPTF as part of a $300-million cooperative program among the United States, Japan, and West Germany.

Brigham Young University to take charge of TRAC development during a crucial phase and is now head of the Energy Division; his deputy, Mike Stevenson, who came from Babcock & Wilcox via Argonne to head the high-temperature gas-cooled reactor analysis effort; Charlie Bell, who came from Atomics International to solve SIMMER heat-transfer and hydrodynamics problems; Walt Kirchner, who finished his doctorate at MIT in time to write TRAC heat-transfer routines; Dennis Liles, an expert in two-phase flow hydrodynamics from Georgia Tech who has been invaluable to TRAC development; John Mahaffy, a postdoctoral astrophysicist from the University of Illinois whose numerical hydrodynamics expertise has made TRAC faster; Rich Pryor, a Savannah River reactor physicist whose experience with methods and large codes was very valuable; Jim Scott, a Hanford fuel-behavior specialist; Ron Smith, from Argonne; Ken Williams, from Georgia Tech; Dominic Cagliostro, from SRI; John Ireland, from General Electric; Thad Knight, from EG&G; and many more. ■